INTRODUCTION TO HEAT TRANSFER IN THE HUMAN BODY

ECE 331 – INTRODUCTION TO BIOMEDICAL ENGINEERING

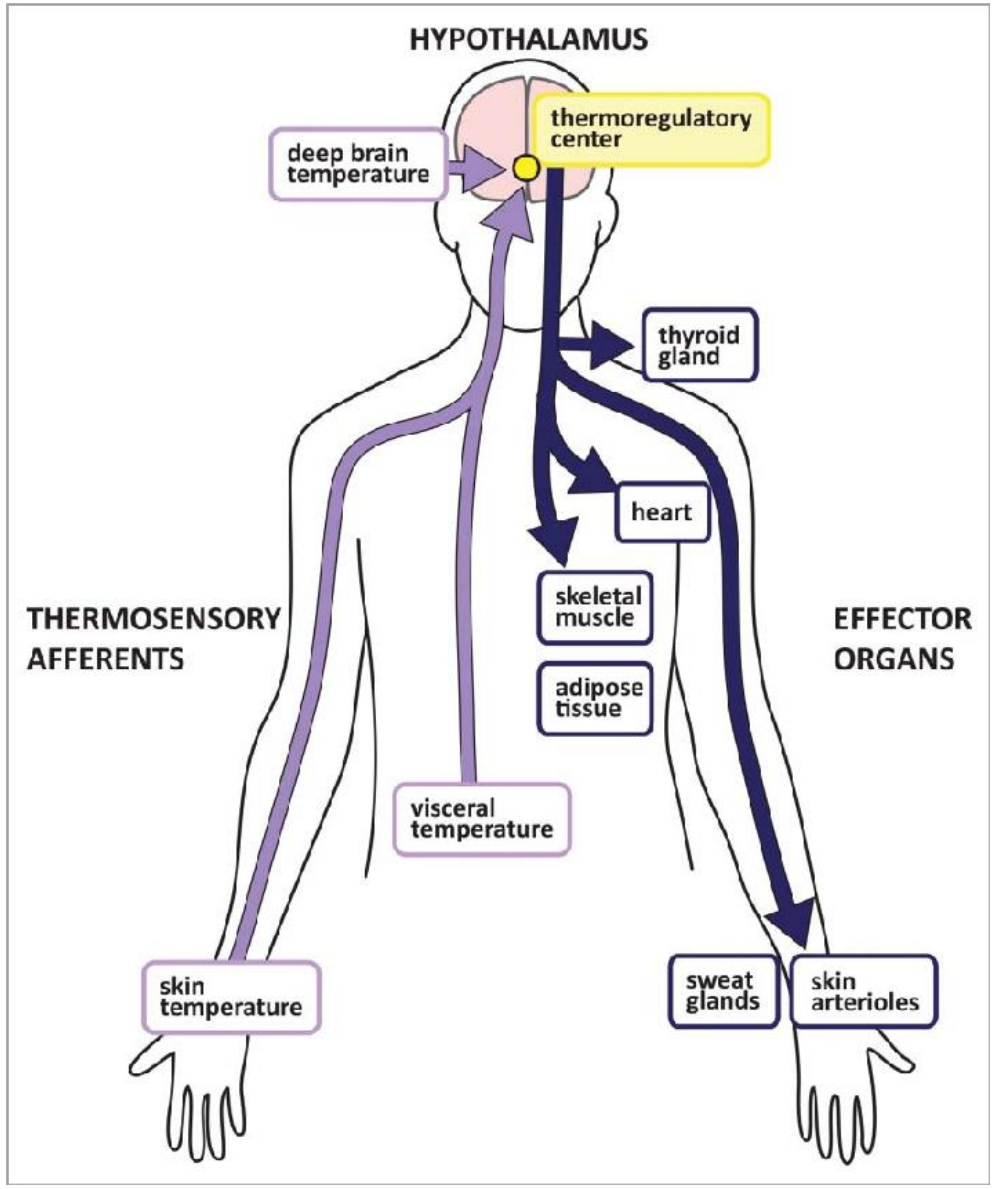
Monday, December 22, 2025

ENERGY & HEAT BALANCE IN THE HUMAN BODY

1. The **human body regulates** the body temperature through a process called thermoregulation.
2. The core temperature of the body is maintained between **36.6°C and 37.5°C**
3. There are four basic heat transfer processes involved in thermoregulation:
   a) Conduction
   b) Convection
   c) Radiation
   d) Evaporation
4. Failure to regulate temperature can result in **hyperthermia or hypothermia**.

HOW DOES THERMOREGULATION WORK?

1. The human body uses three mechanisms for thermoregulation:
   a) **Efferent (inwards) responses:** behaviors that humans can engage in to regulate their own body temperature, e.g. putting on a coat before going out and moving into the shade.
   b) **Afferent (outward) sensing** using a system of temperature receptors around the body to identify whether the core temperature is too hot or cold. The receptors relay the information to the hypothalamus.
   c) **Central control** where the hypothalamus uses information it receives from afferent sensing to produce hormones that alter body temperature.

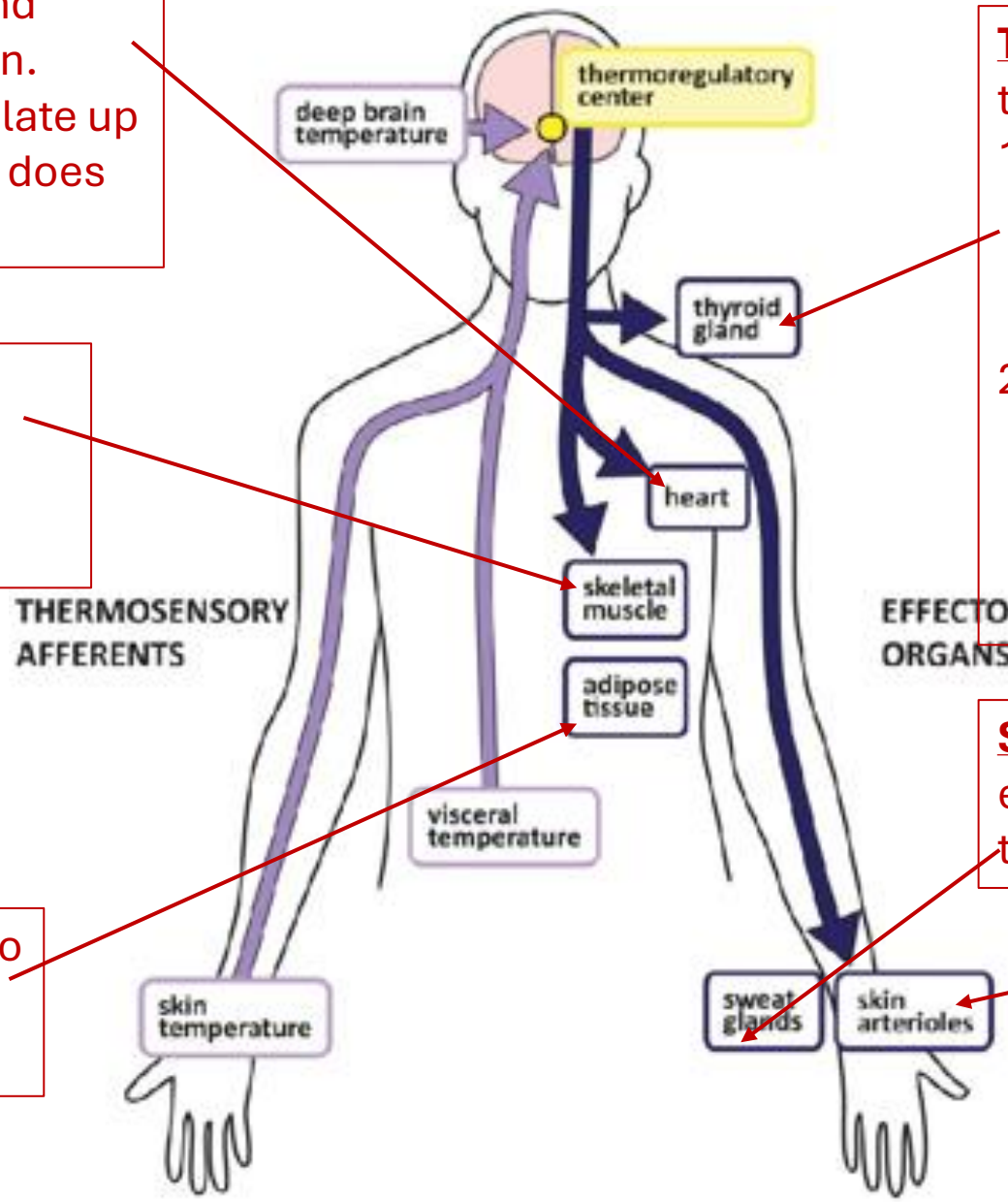


<u>The Heart</u> pumps blood faster and harder to help the body cool down. On a hot day, the heart may circulate up to four times as much blood as it does on a cold day.

<u>Skeletal muscles</u> produce heat during:

- Shivering (thermoregulation)
- Exercises

Adipose Tissue produces heat to maintain body temperature, especially in cold conditions.



<u>Thyroid Gland produces</u> thyroid hormones which:

1. increase heat production by **stimulating metabolic pathways** that deliver energy to tissues.
2. Activate mitochondrial uncoupling proteins, which increase **oxygen consumption**, basal metabolic rate, and heat production.

<u>Sweat Glands</u> produce sweat which evaporates, cooling the skin and the tissues underneath.

Arterioles dilate, which increases blood flow to the skin and allows more heat to be lost through radiation

CENTRAL CONTROL

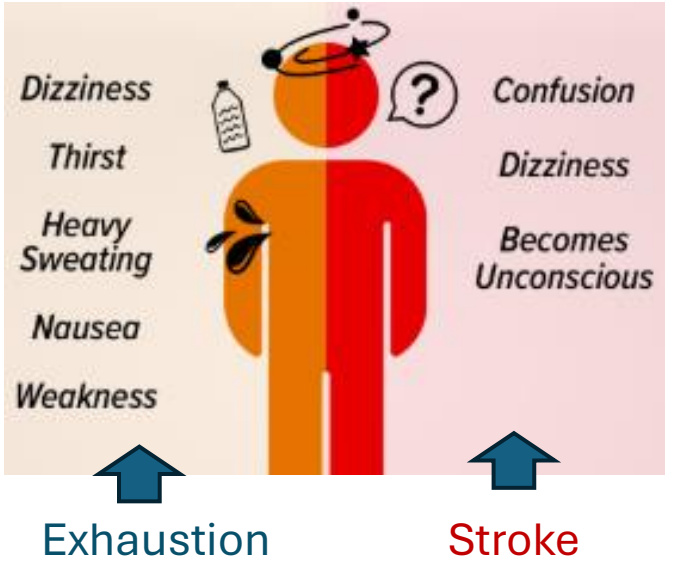
- **The hypothalamus** acts as the central control, using the information it receives from afferent sensing to produce hormones that alter body temperature.
- **The hormones** send signals to various parts of the body so that it can respond to heat or cold in the following ways:

RESPONSE TO HEAT	RESPONSE TO COLD
Sweating	Shivering, or thermogenesis
Dilated blood vessels (vasodilation)	Constricted blood vessels (vasoconstriction)
Decrease in metabolism	Increase in metabolism

Watch Video: The Hypothalamus: The Body's Thermostat

THERMOREGULATION DISORDERS-HYPERTHERMIA

1. **Hyperthermia** occurs when the body's heat-regulating mechanisms fail, and the body temperature becomes too high.
2. The following are types of hyperthermia:
   a) **Heat cramps**, which present as heavy sweating and muscle cramps during exercise.
   b) **Heat exhaustion**, which is more serious and causes a range of symptoms
   c) **Heatstroke**, which is a medical emergency

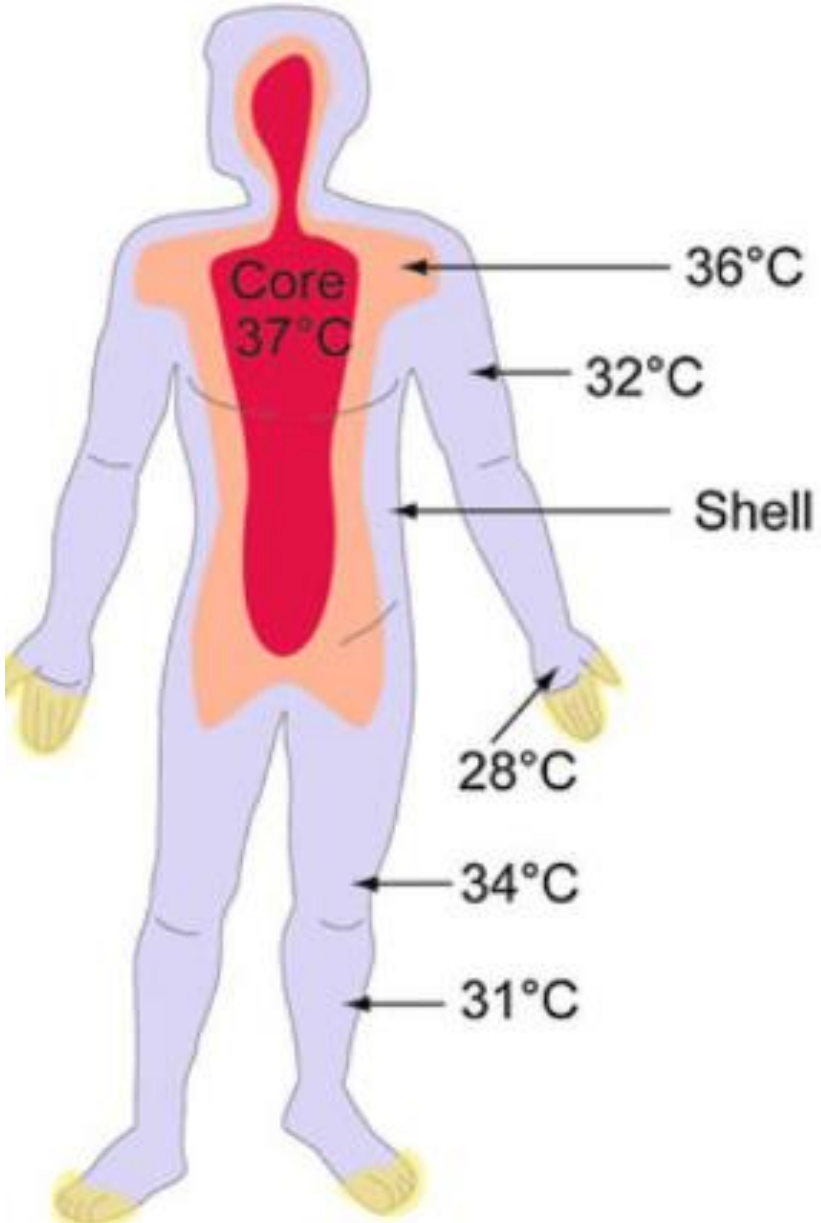


THERMOREGULATION DISORDERS-HYPOTHERMIA

1. **Hypothermia** occurs when the body loses heat faster than it can produce it.
2. The following are symptoms of hypothermia:
   a) shivering
   b) confusion
   c) exhaustion or feeling very tired
   d) fumbling hands
   e) slurred speech
   f) drowsiness
   g) memory loss

TEMPERATURE DISTRIBUTION IN THE HUMAN BODY

1. **Temperatures varies** from 37°C in the core and central organs, such as the spleen to as low as 28°C in peripheral organs.
2. Temperatures also **vary slightly in response to several physiological and pathophysiological** conditions.

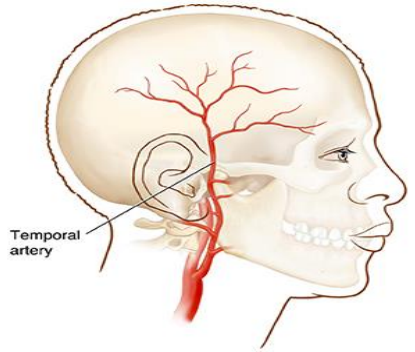


MEASUREMENT OF BODY TEMPERATURE /01

In general, there are two types of thermometers i.e **touch (or contact)** and **remote (or no contact)**.

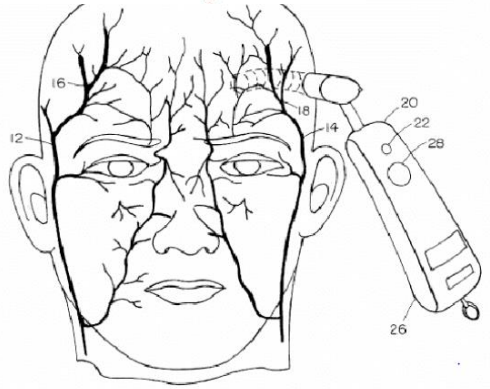
TOUCH (OR CONTACT) THERMOMETERS

1. **Oral:** A thermometer is placed under the tongue.
2. **Rectal:** A lubricated thermometer is inserted into the anal canal. Rectal temperatures are usually 0.5–1.0°F higher than oral temperatures.
3. **Axillary:** A thermometer is placed in the armpit. Axillary temperatures are usually 0.5–1.0°F lower than oral temperatures.
4. **Tympanic:** A thermometer is placed in the ear.



REMOTE (OR NO CONTACT) THERMOMETERS

6. **Temporal Artery Thermometer:** A remote thermometer uses an infrared scanner to measure the temperature of the forehead.



CLINICAL MEASUREMENT OF TEMPERATURE

1. **Mouth:** Place the probe under the tongue and close the mouth. Breathe through the nose. Use the lips to hold the thermometer tightly in place. Leave the thermometer in the mouth for 3 minutes or until the device beeps.

2. **Rectum: This method is for infants and small children.** They cannot hold a thermometer safely in their mouth. Place petroleum jelly on the bulb of a rectal thermometer. Place the child face down on a flat surface or lap. Spread the buttocks and insert the bulb end about 1/2 to 1 inch (1 to 2.5 centimeters) into the anal canal. Remove after 3 minutes or when the device beeps.

3. **Axillary (Armpit):** Place the thermometer in the armpit. Press the arm against the body. Wait for 5 minutes before reading or when the device beeps.

CLINICAL MEASUREMENT OF TEMPERATURE /02

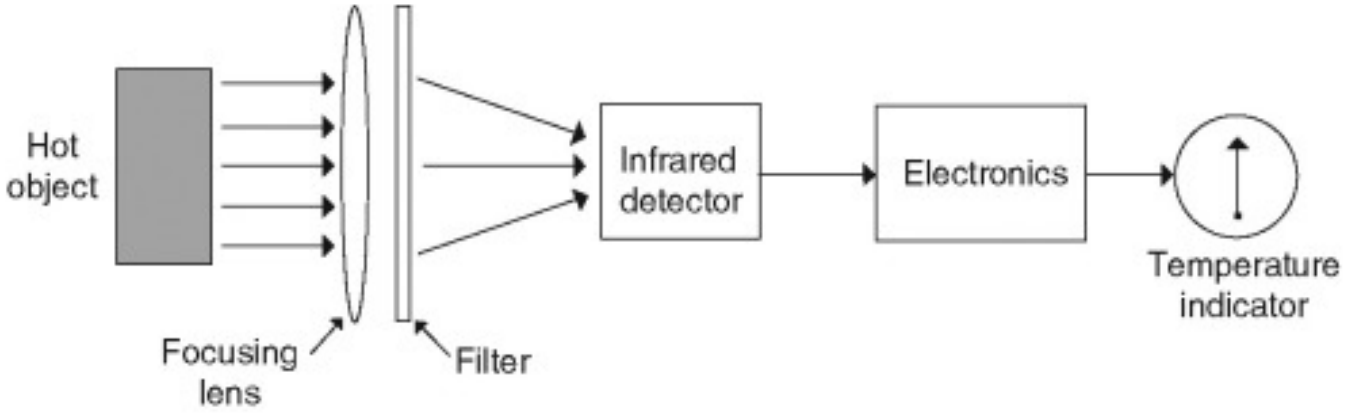
4. **Tympanic:** Gently pull the ear up and back to straighten the ear canal. For children under three, pull the ear downward and back. Insert the tip of the thermometer into the ear canal until it stops. Activate the device. Wait for the thermometer to beep,

5. **Temporal Artery Temperature (TAT) measurement:** A method for measuring body temperature using an infrared scanner to detect heat from the skin over the temporal artery in the forehead. The thermometer is moved from the center of the forehead to the hairline to estimate core temperature in a few seconds

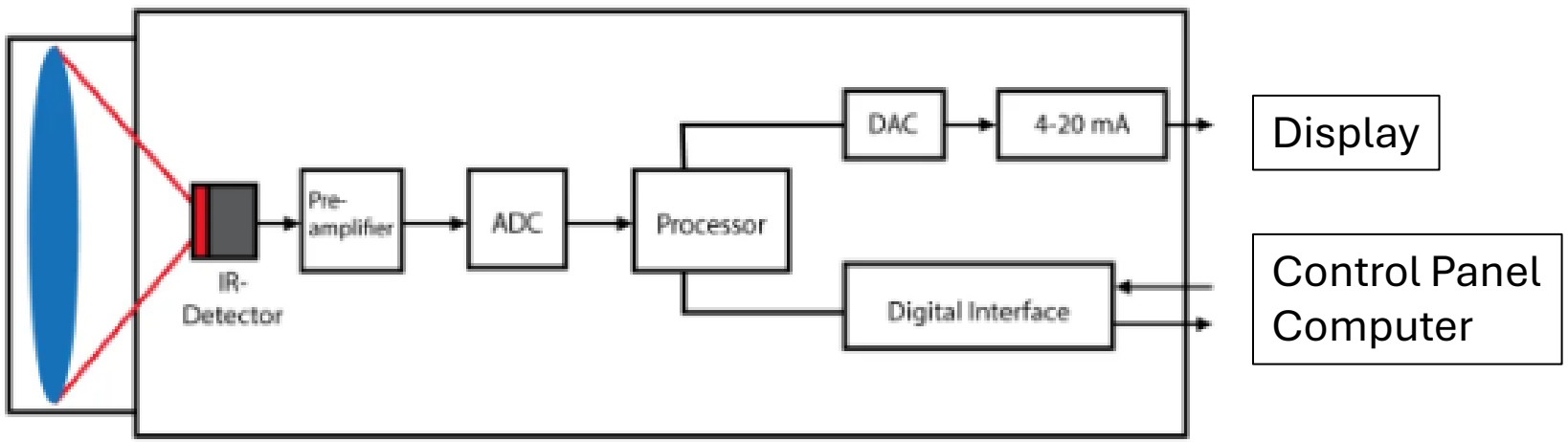
HOW THE INFRARED THERMOMETER WORKS

1. **Infrared thermometers** use infrared radiation to measure the temperature of an object without physical contact using the following steps:
    1. **Focus:** The thermometer's lens focuses infrared radiation from the object onto a detector called a thermopile.
    2. **Convert:** The thermopile converts the infrared radiation into an electrical signal.
    3. **Amplify:** The signal is amplified and converted into voltage.
    4. **Calculate:** The thermometer applies a temperature equation based on Planck's Radiation Law to process the output.
    5. **Display:** The temperature reading is displayed on the thermometer's screen.
2. **Some infrared thermometers** perform additional tasks such as compensation for external factors like emissivity and ambient temperature, Store readings, and Include a laser pointer for precise aiming.

Watch Video: How infrared imaging camera works



(a) Infrared Thermometer principle



(b) Infrared Thermometer with digital interface

Watch Video: How Does An Infrared Thermometer Work?

ADVANTAGES & DISADVANTAGES OF TEMPERATURE CONTACT MEASUREMENT

ADVANTAGES

- Most electronic contact thermometers can record temperatures from the **forehead, mouth, armpit or rectum — often in less than one minute.**
- An electronic contact thermometer is **appropriate for newborns, infants, children and adults.**

DISADVANTAGES

- Parents may worry about causing discomfort when taking a child's temperature rectally.
- You need to wait 15 minutes after eating or drinking to take an oral temperature. Otherwise, the temperature of your food or drink might affect the thermometer reading.
- It can be difficult for children — or anyone who breathes through the mouth — to keep their mouths closed long enough to get an accurate oral reading.

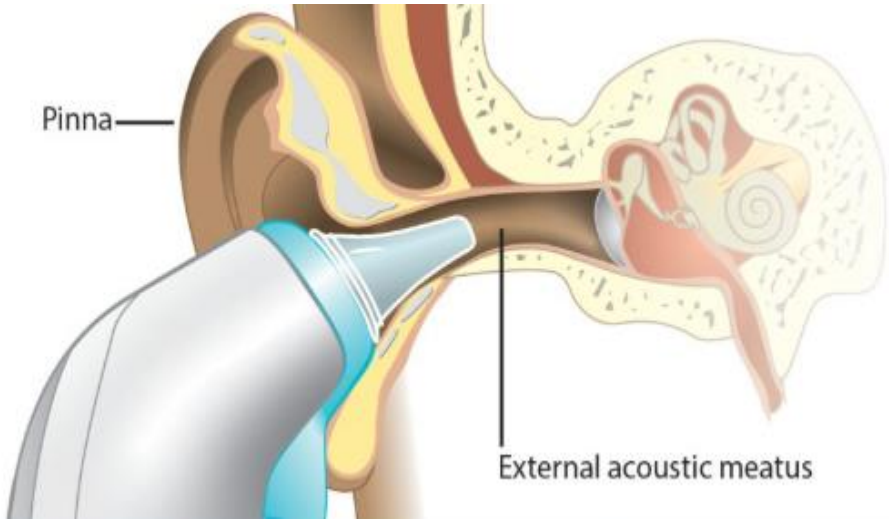
ADVANTAGES & DISADVANTAGES OF TYMPANIC THERMOMETERS

ADVANTAGES

Tympanic thermometers offer fast and accurate readings, and it is preferable to assess both oral and rectal thermometers, especially in children

DISADVANTAGES

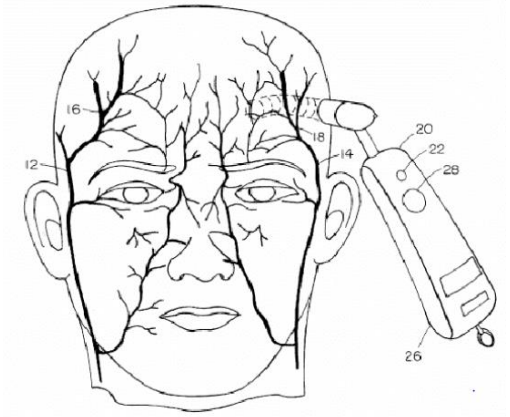
1. **Tympanic thermometers** are not ideally suggested for infants less than 6 months old
2. It must be placed properly to get precise results
3. Obstructions like earwax may alter the results
4. They may not suit small or curved ear canal



ADVANTAGES & DISADVANTAGES OF TEMPORAL ARTERY TEMPERATURE (TAT) MEASUREMENT

ADVANTAGES

1. A remote **temporal artery thermometer** can record a person's temperature quickly and are easily tolerated.
2. Remote temporal artery thermometers are appropriate for children of any age.



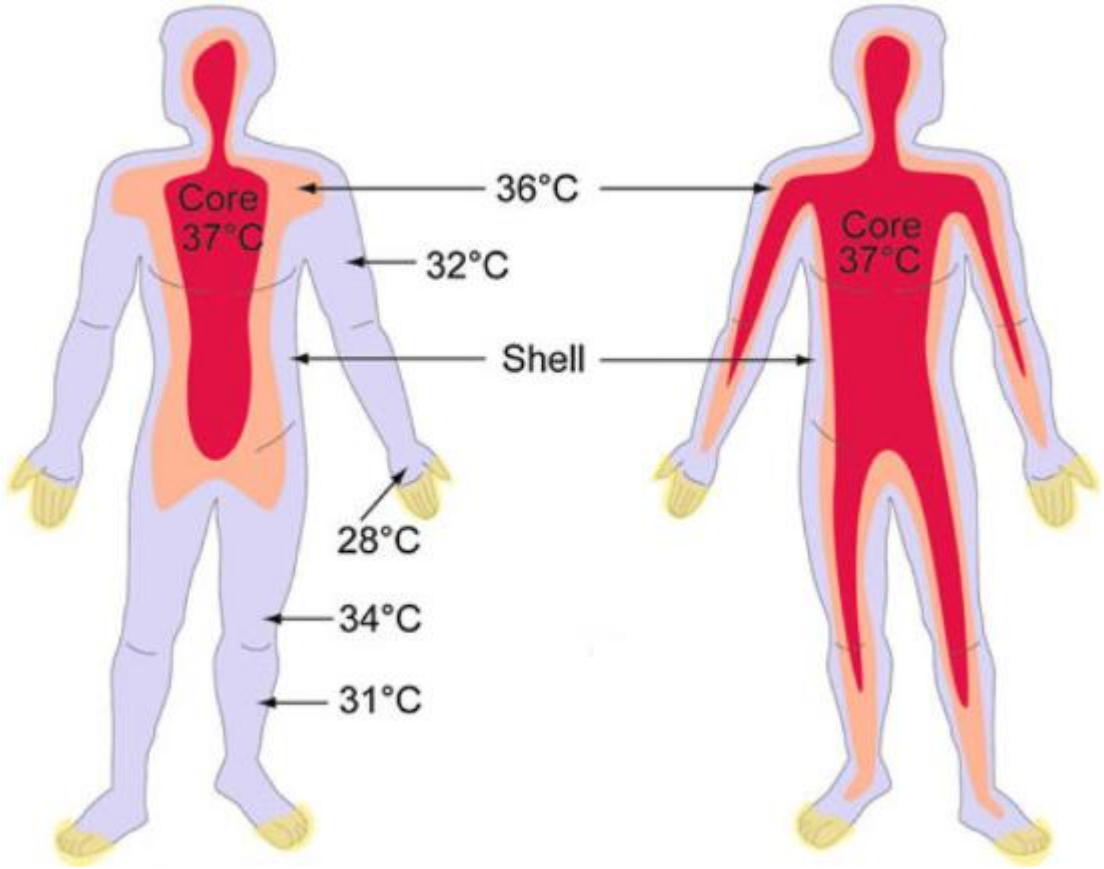
DISADVANTAGES

1. A temporal artery thermometer is more expensive than other types of thermometers.
2. It may be less accurate than other types.
3. Direct sunlight, cold temperatures or a sweaty forehead can affect temperature readings.
4. Variations on user technique, such as holding the scanner too far away from the forehead, also may affect accuracy.

VARIATIONS IN CLINICAL TEMPERATURE MEASUREMENTS /01

1. The average normal body temperature is (37°C).
2. However, normal temperature can vary due to things such as:
    1. **Age** (in children over 6 months, daily temperature can vary by 1 to 2 degrees Fahrenheit)
    2. **Differences among individuals**
    3. **Time of day (often highest in the afternoon)**
    4. Which type of measurement was taken (**oral, rectal, forehead, or armpit**)

VARIATIONS IN CLINICAL TEMPERATURE MEASUREMENTS /02



(a) Cool ambient temperature (b) Warm ambient temperature